THE INFLUENCE OF TECHNOLOGY ON THE PRODUCTIVITY OF KANSAS AGRICULTURE, 1909-1954

by

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B. S., Kansas State University, 1959

A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Economics and Sociology

KANSAS STATE UNIVERSITY
OF AGRICULTURE AND APPLIED SCIENCE

1960

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INTRODUCTION

Technological progress has been a well-known phenomenon to economists, but a phenomenon which they admittedly have not fully explained. Technological progress has not been easy to define or measure. Nevertheless, almost all would agree that it has been observed in history. Technological change has been one of the more important forces altering the structure of the agricultural production process. The physical and value productivity of farm resources has changed continuously under the flow of technology in agriculture over the past half century.[1]

Hybrid seed corn has replaced open-pollinated seed corn. The self-propelled combine has replaced the threshing machine. The farmer has increased his production per hour twofold in one generation by using a tractor in place of a team of horses.[2] These changes in agricultural production have represented technological change. Technological progress has occurred if these changes increase the ends relative to the means employed.[3] Technological progress apparently has been something real, but a complete explanation of this phenomenon must depend upon a more accurate understanding of its nature.

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[1] E. O. Heady, "Economics of Agricultural Production and Resource Use," p. 794.

[2] Glen T. Barton and Reuben W. Hecht, "Gains in Productivity of Farm Labor," U.S.D.A. Technical Bulletin No. 1020, Dec. 1950, p. 1.

[3] Kenneth E. Boulding, "Economic Analysis," p. 716.

Technological progress has occurred as a result of advances in the techniques of production.[4] Since techniques have been considered to be ideas, technological progress may take the form of new ideas applied to given resources and/or it may result from the employment of new resources in conjunction with new ideas.[5] Generally, technological progress has employed factor-saving techniques, factor-using techinques, and/or output-increasing techniques.[6] Improvements in the techniques of production, then, have been the basis of technological progress. New techniques or improvements in the existing techniques have generally been accepted if they increased the ends relative to the means.

Researchers have attempted to measure technological change by several methods. From what has been learned about the nature of technological progress, it lends itself most favorably to four methods of measurement.[7] These measurements of technological progress have been expressed in terms of output per unit of land, output per unit of labor, output per unit of capital, and output per unit of total input. Total input has been calculated by adding the three conventional factors of production land, labor, and capital.[8]

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[4] Vernon W. Ruttan, "The Contribution of Technological Progress to Farm Output," The Review of Economics and Statistics, Vol. XXX, May 1948, p. 62.

[5] Glenn L. Johnson and Curtis L. Lard, Unpublished manuscript for the Interstate Managerial Study, Defining Technology.

[6] Heady, op. cit., p. 802.

[7] Ibid., p. 795.

[8] Ibid., p. 24.

Management, the influence of the entrepreneur, has often been considered one of the conventional factors of production affecting technological progress.[9] However, management has not been used as a means of measuring technological progress since its influence on production has not been measured satisfactorily. Any influence of management on production generally has been figured as a qualitative change in the labor factor of production.

Technological progress has been affected by several factors other than the conventional factors of production land, labor, and capital. Changes in the other factors of production such as national government programs, climatic conditions, plant and animal diseases, insects and pests, local government, and customs and mores of the community influence the production of agricultural products to varying degrees. Changes in these factors have affected technological progress either directly or indirectly through their influence on agricultural production.

The effect of such factors on technological progress has been hard to establish due to the difficulty of measuring their influence on agricultural production. For example, government agricultural programs designed as price and income stabilizing may directly control production by limiting the number of acres planted to certain crops. On the other hand, government programs may indirectly encourage production by supporting the prices of certain crops or products, thus decreasing price uncertainty in

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[9] Ibid., p. 24.

management decision-making. The exact influence of government programs on agricultural production has been somewhat of a mystery to the economist.

Another example of a factor affecting technological progress through its influence on agricultural production has been the climate of a geographic area. Climatic conditions influence the production of agricultural products to varying degrees, depending on such factors as soil, type of crop, breed of livestock, and/or intensity of the climatic conditions. The intensity of the climatic conditions can be measured in terms of inches of rainfall, degrees of temperature, days of sunshine, rate of evaporation, level of soil moisture, and wind velocity.

Even though climatic conditions can be measured, only limited knowledge has been accumulated regarding their influence on the production of agricultural products. Both the intensity of climatic conditions and the characteristics of soil have been largely governed by nature, and vary widely from one geographic area to another. The combination of these two factors in a favorable relationship has determined, in large part, the capabilities of any geographic area to produce agricultural products. Irrigation and fertilizer have been used by man to reduce the adverse influence or complement the beneficial influence of climatic conditions. New varieties of crops and improved breeds of livestock have been used by man to adapt more satisfactorily to the climatic conditions within a geographic area. New techniques have been continually employed to reduce the adverse effects, and exploit the

favorable influences of climatic conditions to promote agricultural production.

In summary, technological progress has remained a phenomenon determined by the influence of new techniques on the conventional factors of production, factors affecting agricultural production, and conditions yet undefined by the economist. Technological progress has been observed and measured, but the complete explanation of its nature and consequences has remained an important area for the economist. Therefore, the analysis undertaken in this study was directed towards gaining a better understanding of the nature and consequences of technological progress.

Nature of the Study

This study was an inquiry into the nature and consequence of technological progress in Kansas agriculture. The study was primarily concerned with the influence of technology on the production of Kansas agriculture during the time period 1909 through 1954. The study attempted to analyze the effects of technology on agricultural production in Kansas by measuring the changes in total agricultural production relative to the means employed in agricultural production. In addition to measuring the input-output ratio over time, this study analyzed the influence of technology on each conventional factor of production land, labor, and capital.

Land was defined for the purposes of this study as total real estate. Total real estate included both land and buildings used

in agricultural production. Labor referred to all human services including decision-making since management was considered a qualitative change in the labor factor of production. Capital was defined as all non-human resources except land.[10] Each of these conventional factors of production was analyzed to determine changes in their absolute quantity and changes in their relative importance to the other factors of production. The analysis of the changes in these factors of production was considered important in gaining a more accurate understanding of technological progress.

Therefore, this study dealt with technological progress primarily through the means of aggregate input-output analysis in an attempt to gain new insights into the influence of new techniques on Kansas agricultural production.

Scope of the Study

This study was limited to Kansas agriculture during the time period 1909 through 1954. The study was narrowed to focus primarily on the growth in production of crop and livestock products during that period of time.

Kansas agricultural production, expressed in dollar values adjusted to 1910-14 prices, increased from a value of $247,369,000 in 1909 to $347,600,000 in 1954. Total agricultural production in Kansas reached a high in 1952 of $399,829,000. Livestock

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[10] Heady, op. cit., pp. 24-25.

production adjusted to 1910-14 prices showed a steady increase during the time period 1909 to 1954 from $34,735,950 in 1909 to $72,553,358 in 1954. Total crop production in terms of 1910-14 prices increased over that same period of time from $212,922,000 in 1909 to $273,284,000 in 1954. These statistics were computed for each year used in the analysis. Statistics showing total agricultural production, total crop production, and total livestock production for each year from 1909 through 1954 in Kansas agriculture are presented in Table 3 (Appendix). The growth in Kansas agricultural production from 1909 to 1954 was clearly evident from these statistics.

The changes in the resources employed in the production of Kansas agriculture indicated the influence of technological improvements on production during the time period from 1909 to 1954. Important changes have taken place in the quantity of individual resources employed in Kansas agricultural production during this time period. Important qualitative changes have also taken place in the productive resources during this time period.

The total number of farm laborers, including both family and hired workers, decreased from a total of 282,000 in 1909 to a low of 200,420 in 1954.[11] The output per laborer increased, however, during this same period. The output per laborer expressed in dollar values adjusted to 1910-14 prices increased from $856.64 per laborer in 1909 to $1,757.42 per laborer in 1954. The decrease

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[11] U. S. Department of Commerce, "1954 Census of Agriculture, Kansas," Vol. I, Part 13, p. 17.

in the number of laborers and the increase in total production during this time period undoubtedly explained part of the increase in output per laborer. In addition to quantitative changes in the number of laborers, some economists, particularly T. W. Schultz, have argued that farm labor has undergone a qualitative upgrading during the past 50 years.[12] Qualitative improvements in management decision-making particularly would facilitate increased output per laborer. Improved management has resulted in the acceptance of new ideas and practices. Improved management has been aided by better school systems, vocational agricultural training, expanded extension service programs, and the general improvement in the means of communication.

This period of Kansas agriculture also was characterized by an increase in machine power and a decrease in animal power employed in agriculture. The mechanization of Kansas farming has been one of the major contributors to increases in labor productivity. One example of increased labor productivity resulting primarily from mechanization has been the reduction of labor requirements for producing an acre of wheat. According to Hecht and Barton, in their estimates of man-hours required to produce an acre of wheat in the United States, a requirement of 15.2 man-hours was necessary to produce an acre of wheat in the 1910-14 period as compared to a requirement of only 6.1 man-hours in the

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[12] T. W. Schultz, "Reflections on Agricultural Production, Output, and Supply," p. 757.

1945-48 period.[13] This trend of increased labor productivity in the production of wheat was further emphasized for Kansas from studies conducted by Scoville and Hodges on wheat production in western Kansas. Their estimates showed that western Kansas wheat farms in 1947, assuming 59 percent continuous cropping, 41 percent summer fallowing, and with one-waying and seeding the only pre-harvest operations, required an average of only 2.21 man-hours and 1.35 tractor-hours to produce an acre of wheat.[14]

The growth in mechanization has brought about other apparent trends in Kansas agriculture by enabling one farm operator to cultivate and manage more acres of land. These trends have been a reduction in the number of farms and an increase in the average size of farms. In 1920 the average size of farm was 275 acres, and total farms numbered 165,285.[15] By 1954, average farm size had increased to 416 acres, and farm numbers had decreased to a total of 120,167.[16] It was interesting to note that acres of cultivated land has remained relatively constant, and production has increased during that period. However, only part of the change in farm size and number of farms was attributed to the

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[13] R. W. Hecht and G. T. Barton, "Gains in Productivity of Farm Labor," U.S.D.A. Technical Bulletin No. 1020, Dec. 1950, p. 70.

[14] Hodges and Scoville, "Practices and Costs on Wheat Farms in Western Kansas, 1947," Kansas Agr. Exp. Sta. Cir. No. 268, 1950, p. 4.

[15] U. S. Department of Commerce, "1954 Census of Agriculture, Kansas," Vol. I, Part 13, p. 3.

[16] Ibid.

growth in mechanization during that time period.

Another important quantitative change in resource use during this time period was the increased application of fertilizer to cropland. The use of commercial fertilizers on Kansas farms has increased sharply in the last 20 years of Kansas agricultural production. The value of commercial fertilizers used in 1939 was only $473,020 as compared to a high of $19,676,479 worth of commercial fertilizer used in 1954.[17] The influence of fertilizer on crop production generally has resulted in increased yields per acre.

Important qualitative improvements have taken place in many productive resources employed in Kansas agriculture during the time period 1909 through 1954. The rapid adoption of hybrid seed corn has been but one example of the many improvements in crop varieties. In 1939 only about five percent of the corn acreage in Kansas was planted with hybrid seed. By 1944 almost half the acreage was planted with hybrid seed, and by 1950 nearly 86 percent was planted with hybrid seed. If the increase in yield from hybrid seed was about one-fifth of the increase in the national average, then the volume of production was materially increased by this practice alone.[18]

New wheat varieties have made sizeable contributions to

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[17] Leo M. Hoover, "Kansas Agriculture After 100 Years," Kansas Agr. Exp. Sta. Bul. No. 392, Aug. 1957, p. 34.

[18] J. A. Hodges, "Progress and Change in Kansas Farming," Kansas Agr. Exp. Sta. Annual Project Report, Feb. 6, 1952, p. 31.

increases in wheat yields.[19] The introduction and wide acceptance of new varieties such as Commanche, Wichita, Pawnee, and Triumph during the time period 1930 through 1954, indicated the effectiveness of state research and extension programs to improve wheat yields. The development of hybrid sorghum seed during the past decade also has indicated a great potential for increasing yields of grain sorghum.

Improved breeding practices, feeding better balanced rations, and the adoption of other improved practices have been leading contributors to increased livestock production. A larger product per unit of livestock has resulted. Two examples are presented:[20] (1) butterfat production per cow for the entire period 1924-50 has increased on the average about one and one-fourth pounds annually; (2) egg production per hen from 1924 to 1950 has shown an annual addition of 1.75 eggs. If only the period 1936-50 is considered, the increase was a little more than three eggs per hen per year. These improvements and other improvements such as these resulting from the influence of new technology in agricultural production have played an important role in the growth in production and technological progress in Kansas agriculture.

In summary, changes in the resources employed in Kansas agriculture during the time period 1909 to 1954 have been many and

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[19] Leo M. Hoover and John H. McCoy, "Economic Factors Affecting Wheat in Kansas," Kansas Agr. Exp. Sta. Bul. No. 369, Jan. 1955, p. 9.

[20] J. A. Hodges, "Progress and Change in Kansas Farming," Kansas Agr. Exp. Sta. Annual Project Report, Feb. 6, 1952, p. 32.

varied. Important qualitative upgrading has occurred in nearly all resources. Significant quantitative changes have taken place in number of laborers, number of machines, number and size of farms, and such items as the quantity of fertilizer and the quantity of money spent on research employed in Kansas agriculture over the past 50 years. These quantitative and qualitative changes in resources were reflected in the measurement of technological progress in Kansas agriculture from 1909 to 1954.

Objectives of the Study

The principal objective of this study was to facilitate a better understanding of the nature of economic progress. By using the data available and means of analysis applicable to input-output analysis, this study worked with Kansas agriculture from 1909 to 1954 in an attempt to gain new insights into the nature of technological progress in Kansas agriculture.

The specific objectives of this study were: (1) to measure the changes in the labor input over time and associate it with changes in output; (2) to measure the quantitative changes in each capital input employed in Kansas agriculture over time and associate it with changes in total output; (4) to measure the changes in total output per unit of total input over time in Kansas agriculture; (5) to determine the degree of association between changes in total input and changes in total output; (6) to isolate the influence of new ideas (technology) on the production of Kansas agriculture; (7) to demonstrate the rate of

technological progress in Kansas agriculture during the time period 1909 through 1954; and (8) to draw inferences about the effect of new techniques on the factors of production employed in Kansas agriculture.

A REVIEW OF THEORIES OF ECONOMIC DEVELOPMENT

The theory of economic development has not been a new concept in economics. The classicists were perhaps the first to develop a model of economic development based on technological progress. J. S. Mill devoted all of Book IV of his famous synthesis of classical economics, "Principles of Political Economy," to the topic of economic development. Smith, Malthus, and Mill were all quite sure that total output depended on the size of the labor force, the stock of capital, the amount of land and resources available, and the level of technology. The classicists assumed technology to be abundant in supply and not a limiting factor to development. They attributed increases in output as primarily a function of technological progress. Technological progress, according to the classicists, was dependent on the level of capital accumulation or investment (the level of capital accumulation was considered to equal the level of investment). Therefore, the classicists upheld that the level of investment directly influences the rate of output growth. Furthermore, the classicists stated that investments depended on profits or increases in the stock of capital. They also believed that profits

depended on the labor supply and the level of technique.[21]

The classicists, therefore, believed that if profits were increased, then the level of investment would increase, and so an addition to the stock of capital, which permits capitalists to take advantage of the steady flow of improved techniques. However, this movement increased the wages fund, which brought an accelerated population growth that caused decreasing returns to labor on the land, raising labor costs and reducing profits.[22]

Harrod explained the classical theory of economic development as a race between technological progress and capital accumulation on the one hand, and diminishing returns to a growing population and to a fixed supply of land on the other.[23]

The classical model had weaknesses when applied to the actual economy which were first pointed out by Malthus, and later explicitly explained by J. M. Keynes. The concept of effective demand distinguished certain factors such as level of employment and future profit expectations, unaccounted for by the classicists, as determinants of the level of technological progress and investment. Also, the classicists did not include in their analysis the managerial and entrepreneurial contributions which have become important elements in later models of economic development. But, aside from the weaknesses in the operation of their model in the actual economy, the classicists have named the

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[21] Benjamin H. Higgins, "Economic Development," pp. 85-87.

[22] Ibid., p. 95.

[23] R. F. Harrod, "Towards a Dynamic Economics," p. 16.

conditions by which economic development would take place. The importance of the level of investment and the growth in technological progress have remained as major elements in any theory of economic development.

Karl Marx, writing in a later time period, used basically the same relationships between profits, investment, and technology as the classicists used. However, Marx introduced the entrepreneur as an important factor in economic growth. Marx also saw that economic growth under capitalism tends to be fluctuating and that economic growth is a destablizing influence. Marx showed that stable economic growth depends on a balance between investment and consumption, and, in addition, a balance between investment and savings.[24]

The concept of economic growth as a destablizing influence was greatly enlarged by Joseph Schumpeter in his book, "Theory on Economic Development." Schumpeter placed great emphasis on the entrepreneur as an innovator or the driving force of capitalism. Schumpeter set up a general equilibrium model in which he analyzed economic change. Having established a state of static equilibrium, Schumpeter brought in an external factor, innovation, to disrupt the equilibrium model. Since the static equilibrium model eliminated profits or surpluses, profits were made only by introducing cost-reducing innovations. An innovation was an invention defined broadly to include new techniques, new methods,

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[24] Higgins, op. cit., pp. 107-109.

and pure inventions. Therefore, in the prosperous, inflationary period, new innovations were introduced and financed by credit based on future expected profits. The inflationary phase was followed by a regressive movement towards equilibrium until another innovation started a forward movement again. The regressive movement was thought to end at a higher level of equilibrium. Thus, the level of economic development was raised by new innovations injected into the economy by the entrepreneur.[25]

Schumpeter, in the final analysis, recognized the innovator as the sustainer of capitalism. Through innovation and the following disruption of equilibrium, a readjustment took place which improved the general welfare by creating greater production. However, Schumpeter saw capitalism slowly dying as the innovator was being subdued by Socialism entering the economy.[26]

Another economist, R. F. Harrod, built a model in which he defined the dynamics of economic development. Harrod was concerned primarily with the "Capital Requirements" of economic growth. Harrod defined capital requirements as the proportion of income that must be saved and invested to maintain a given rate of increase in income, with a given rate of technological progress and a given rate of population growth. Therefore, the basis of economic development was sufficient investment to maintain continued growth in income. Harrod regarded increased income to be a result

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[25] Ibid., pp. 122-129.

[26] Ibid., pp. 139-143.

of investment in technology to increase resource productivity. Thus, Harrod returned to the basic model of the classicists in emphasizing the importance of investment in technology being fundamental to economic development.[27]

Economists, writing in the past decade on the economics of agricultural development, have been concerned with an analysis of the factors of input as they affect changes in output. E. O. Heady of Iowa State University and T. W. Schultz of the University of Chicago are two agricultural economists who have contributed to a better understanding of economic progress as it is influenced by technological developments affecting resource productivity. Each man, however, has approached the input-output analysis of agricultural production somewhat differently.

Heady has considered discovery, innovation, and capital accumulation to be the foundation of economic progress. He has considered innovations to be either factor-saving, factor-using, or output-increasing when applied to agricultural production. These innovations have resulted in increased production relative to the means used. Innovations have been considered to be mechanical or biological. Biological innovations have been defined as having a physiological effect in increasing the total output per acre, per animal, per feed unit from a given land base. Mechanical innovations have appeared as machines which substitute capital for labor, but do not change the physiological

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[27] Harrod, op. cit., pp. 83-91.

outcome of plants and animals to which they are applied. However, innovations generally have combined elements of both biological and mechanical characteristics. Heady has considered innovations always to be output-increasing in the aggregate. Innovations also have altered the marginal physical rates of substitutions of productive resources in favor of one resource or group of resources.[28]

Heady has emphasized that innovations are adopted only if they lower the value of inputs relative to outputs. Heady argued that the relatively high substitution rates and relatively low prices for new innovations have made it physically simple for output to increase without a similar increase in total value of inputs. He has pointed out that land grant education, alone, in its efforts to move "less efficient" farmers to the position of the "more efficient" farmer, would result in the production of a greater output with the same or smaller quantity of resources. Therefore, Heady has listed three factors of primary importance in explaining a lowering of inputs relative to output as agricultural production increases. They were: (1) the substitution effect of substituting a more efficient resource or innovation for a less efficient one; (2) the price effect of changes in relative prices of factors of production; (3) the scale or cost economies resulting from farm consolidation and specialization.[29]

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[28] Heady, op. cit., pp. 813-820.

[29] Ibid., pp. 805-812.

While Heady has concentrated on explaining an increasing ratio of input/output, T. W. Schultz has argued that the actual input/output ratio remains constant and at a value of 1. Schultz has emphasized that growth in output cannot be explained satisfactorily by an analysis which is based on conventional inputs. Schultz has believed that a 1/1 ratio of input/output can be approximated by including two variables which have been largely neglected in input/output analysis. These variables were: (1) the new techniques that are adopted in production; (2) the improvements in the labor force; that is, in the quality of people engaged in production. He has emphasized that additional inputs of capital and effort must be accounted for as responsible for improvements in the quality of workers and for the discovery of new techniques of production.[30]

Schultz has argued that present studies using conventional inputs of land, labor, and capital do not measure changes in the quality of resources because such studies assume constant returns to inputs. Schultz has believed that a large part of the changes in resource quality resulting from the modern process of technological research from "pure" science to successful practice can be explained by economic analysis. This belief has led Schultz to state that the ideal input-output formula is:

$$\frac{\text{output}}{\text{input}} = 1 \text{ or close to } 1$$

Schultz has been supported in this belief by Zvi Griliches, also

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[30] Schultz, op. cit.

of the University of Chicago.[31]

Both Schultz and Heady have emphasized the importance of new technology or innovations as direct influences on increased resource productivity. Both economists, in studying improvements in resource productivity resulting from new technology, have recognized the unevenness of technological advancements. Heady has emphasized four reasons for the unevenness of technological advancement.[32] They were: (1) the uncertainty of transformation coefficients of resources; (2) the uncertainty of the period of transformation; (3) the amount of capital required; and (4) the differences in managerial requirements. Schultz proposed three hypotheses regarding the rate at which new production techniques appear.[33] They were: (1) that new techniques are unpredictable events; (2) that new techniques are an institutional and cultural product (he emphasized that Western values have placed science in a dominant position); and (3) that pure science and its contribution to society are closely interrelated. The analysis of the rate of technological advancement and resulting economic progress has been tied to many interrelated and separate factors in the economy and society. Some factors have been cultural and psychological in nature as they influence economic progress. Other factors such as resource productivity, managerial ability, and profit expectations of the future have

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[31] Ibid.

[32] Heady, op. cit., pp. 808-809.

[33] Schultz, op. cit.

determined largely the rate of economic progress.

The variety of theories of economic development has been expressed quite well by T. W. Schultz in the following statement:

> The economics of development, at this stage of our knowledge, is more akin to a collection of ideas and studies representing different approaches. Some approaches are cast in biological mold and concentrate on the growth attributes of the economy; some single out the economic effects of specialization; some place a particular class of entrepreneurs in the role of key innovators; some trace the economic effects of changes in particular factors, be it population, capital, or land; there is the magnificient approach to economic progress of the older English economists (the classical school); there is the particular interpretation of economic history of Marx; and then there are the various bits and pieces from static analysis involving time and form process analysis.[34]

A REVIEW OF STUDIES ON TECHNOLOGICAL PROGRESS

Glen T. Barton and Martin R. Cooper, in their study of United States agriculture entitled "The Relation of Agricultural Production to Inputs,"[35] employed aggregate input-output analysis techniques. Their study covered the time period 1910 to 1945. They measured the effects of technological progress in terms of production per unit of land; production per unit of livestock; production per unit of labor; production per unit of power and machinery; production per combined unit of labor, power, and

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[34] Ibid.

[35] Glen T. Barton and Martin R. Cooper, "The Relation of Agricultural Production to Inputs," The Review of Economics and Statistics, May 1948, pp. 117-126.

machinery; and production per unit of all inputs.

They found that practically all the increase in total crop production since World War I has resulted from greater production per acre. Acreage of total cropland changed very little. They concluded that the marked increase in production per acre during World War II resulted from three broad factors, each about equally important: (1) more favorable weather in the war period than in the prewar period; (2) increased use of commercial fertilizer; and (3) increased use of improved crop varieties, of hybrid corn, of lime, of soil-improvement practices, etc.

Their analysis of production per unit of labor showed that several factors have been responsible for the upward trend in gross production per man-hour. They estimated that increased mechanization of farm operations has been responsible for 50 percent of the increase in labor productivity; increases in crop yields have been responsible for 20 percent; and increases in production per animal and in size of livestock enterprises have been responsible for 10 to 15 percent.

They found from their analysis of production per unit of all inputs that the output per unit of all inputs showed an upward trend since World War I as a result of a remarkable stability of total inputs and a steady upward trend in the volume of farm output. They concluded that increases in physical efficiency in agriculture have been brought about by increasing production per unit of input rather than by decreasing total inputs. The various technological developments that resulted in increased efficiency

also resulted in greater total volume of farm output.

The authors were aware that the techniques of their input-output analysis had certain limitations. A major limitation was the inability to evaluate quality changes in both inputs and outputs. The use of "price deflators" raised some questions of accuracy in adjusting dollar values to a base period. Some pitfalls also existed in the attempt to apply a cash-cost rate to non-cash input items. They concluded that because of the complexity of United States agriculture, much more research on productivity by regions and by types of farms must be done before anything approaching a complete story can be told.

Vernon W. Ruttan, in his bulletin "Technological Progress in the Meat Packing Industry; 1919-47,"[36] concluded that technological progress has not been spectacular, but it has made a significant contribution to increasing the output of the industry. Ruttan discovered a number of problems involved in measuring change in an industry over a 30-year period. In consequence, considerable attention was given in his study to the analytical framework and techniques to be employed in measuring technological progress. On the basis of his study he concluded that the net input-output approach is superior to either the measurement of labor productivity or the production-function approach in measuring technological progress.

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[36] Vernon W. Ruttan, "Technological Progress in the Meat Packing Industry; 1919-47," U.S.D.A. Marketing Research Report No. 59. Jan. 1954, pp. 1-10.

Ruttan's computations based on the input-output approach indicated that the input required by the meat packing industry to produce a given output probably fell, by roughly 25 percent or more, from 1919 to 1947. This represented a growth in technological progress of approximately one percent per year. Reduced input of capital and an increased output from a given volume of livestock were found to be the two principal reasons for this progress. Ruttan concluded that further significant increases in efficiency in the industry, as a whole, will be dependent on further technological developments, particularly those that will make possible the performance by mechanical means of certain tasks that are now done by labor, rather than on the wider adoption of present techniques.

John Sjo, Department of Agricultural Economics at Kansas State University, studied the influence of technology on the production of wheat during the time period 1924 to 1954 in four major wheat-producing regions in the United States. He found that the influence of technology on resource productivity was sporadic. A rapid increase in the growth of technological progress was evidenced in the period 1934 to 1944. This rapid growth was followed by a period from 1944 to 1954 in which little growth was observed and no apparent trend was indicated. Sjo observed that a close association existed between the level of farm income and the gain in production relative to means in his study. In the regions of higher farm income he found that production relative to means was higher than in regions of lower farm income.

These findings were derived from aggregate input-output analysis and labor-output analysis.[37]

METHODOLOGY

The Theoretical Model

This study was designed to measure the influence of new technology on production of Kansas agriculture during the time period 1909 through 1954. The theoretical model of this study on technological progress was patterned after models used by Barton and Cooper in their study of United States agriculture, Ruttan in his study of the meat packing industry, and Sjo in his study of the wheat industry. The methodology employed in this study was similar to that used by these men in their studies of technological progress. The methodology used in this study, however, was adapted to conform with the limitations of available data for the State of Kansas.

The theoretical model of this study was interpreted in the following manner. Techniques were defined as new ideas or new knowledge. New ideas were assumed to influence the input-output ratio through the sbustitution of more-productive resources for less-productive resources and/or through qualitative improvements in the resources employed in agricultural production. Technological progress occurred when resource substitution and qualitative improvement acted to increase production relative to the

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[37] John Sjo, "Technology; Its Effect on the Wheat Industry," unpublished Ph.D. Dissertation, Dept. of Agr. Econ., Michigan State University, 1960, pp. 10-20.

means used in production. Therefore, if the means used in production were assigned a value measuring quantitative changes, then quantitative changes in production relative to changes in the means employed indicated the effect of new ideas or new knowledge. The quantitative measurement of changes in each component of the total bundle of productive inputs clarified the substitution effect of more-productive resources for less-productive resources due to the effect of new techniques. Any increase in production relative to inputs was attributed to the combined influence of resource substitution and qualitative improvement in resources.

The methodology used in the study was designed in accordance with the theoretical model outlined above. The total output of Kansas agriculture was calculated by adding total crop production to total livestock production. Total input into Kansas agriculture was computed by adding total land input, total labor input, and total capital input. Total land input included both land and buildings. Total labor input included family and hired labor. The total input of capital was computed by adding inputs of machines, seed, animal power, fertilizer, and agricultural experiment station research. These values were calculated for several different points in time. From these values the changes in total output relative to total input over time were computed, thus providing a measure of the influence of technology. This study also recognized that total output was influenced by factors other than the conventional factors of production land, labor, and capital. Thus, the changes in ourput relative to input were attributed to

new technology plus unexplained variables.

The output per unit of total input measurement of technological progress in Kansas agriculture was supplemented by measurements of technological progress in the form of output per unit input of labor, ourput per unit input of land, and output per unit input of capital. These measurements of productivity helped to classify the type of new technology as being capital-using, labor-saving, and/or output-increasing.

Limitations of the Analysis

Certain limitations in computing total output and total input were recognized by the author. A major limitation was the inability to measure certain factors which affect agricultural production. The difficulty of measurement was apparent in attempting to assign a value to management. Similar difficulty was encountered in measuring the influence of government programs. The influence of climatic conditions on agricultural production was difficult even though their quantitative values were measured. It was difficult to measure quantitative changes in certain factors, but it was almost impossible to measure qualitative changes in productive resources.

Another apparent limitation was that of securing data to fill gaps in time series data. Often the data were unavailable or were available in a form inappropriate for use in this analysis. Another limitation was that available data did not account for the non-homogeneity of inputs and outputs in the study.

The limitation on available data limited the number of years in which total inputs could be computed. Input data were available in five-year intervals starting in 1909. The five-year intervals corresponded to agricultural census years. Input data for other years were estimated from the data available in five-year intervals.

Additional difficulty was found in attempting to measure the movement of quantities of inputs and outputs across state boundaries. Since this analysis considered only Kansas agricultural production, it was desirable to account for movements of inputs and outputs across state boundaries. However, the data available were not sufficiently complete to compute this movement accurately. Therefore, it was assumed that the net gain or loss from movements across state boundaries was zero.

Furthermore, limitations were encountered when data were not recorded in the same unit of measure. The need for computing one index for total inputs required adding units of each input together. A weighted index was not computed because certain inputs were available only as total values for a year and not as units of input. Inputs of fertilizer and extension research expenditures were a case in point. Therefore, it was necessary to compute the value for each input in dollars so they would all have a common unit of measurement. To maintain a common denominator among inputs and total output, total output was computed by adding dollar values of crop production and livestock production together. All dollar values were then expressed as constant dollar

values in terms of 1910-14 prices.

The difficulty involved in measuring certain factors which influenced agricultural production defined what inputs were to be used in the analysis. The inputs which were most accurately measured were: (1) land and buildings; (2) labor; and (3) capital which included fertilizer, seeds, machines, animal power, and research expenditures. Other factors which influenced agricultural production were not measured directly in the analysis, and were assumed to remain constant for the purpose of the analysis.

Three measurements of technological progress, output per unit of labor, output per unit of land, and output per unit of capital have been questioned as accurate measurements of technological progress due to their tendency to overstate and understate the effect of new technology. The overstatement or understatement has been the result of the techniques employed in technological progress. An example of understatement occurred in the meat packing industry where technological progress during the past 20 years apparently has been primarily capital-saving rather than labor-saving, causing the change in productivity measured in terms of labor to understate the contribution of technological change to changes in output.[38]

The use of "price deflators" in the form of price indexes has been questioned in other technological studies. Their accuracy of adjusting dollar values to constant dollar values of

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[38] Vernon W. Ruttan, "The Contribution of Technological Progress to Farm Output," The Review of Economics and Statistics, Vol. XXX, May 1948, p. 62.

a base period has not been determined. An additional limitation was recognized in the attempt to apply a cash-cost value to a non-cash input item. An example of the last limitation was assigning a dollar value to the family labor input.

Sources of Data

The sources of data were determined in most cases by the availability of proper data. The Kansas Biennial Reports published by the Kansas State Board of Agriculture were the most complete report on Kansas agricultural production for the period 1909 through 1954. Raw crop production and livestock production data were taken from these reports for each year in the analysis. The United States Census of Agriculture for Kansas, published by the Department of Commerce, was the most accurate source of the value of resources employed in Kansas agricultural production. The value of fertilizer inputs, machine costs, and land and building inputs were all obtained from the census reports. Seed values and animal power inputs were computed from the Kansas Biennial Reports. Agricultural experiment station research values were obtained from the Agricultural Experiment Station Financial Reports. The U. S. Department of Agriculture Farm Labor Reports supplied additional information on numbers of farm laborers and average annual wages of farm laborers. The U.S.D.A. Major Statistical Series, Volume 2, was extremely useful in providing percentage factors to compute feed costs as a percent of total livestock value. All livestock production values were adjusted

by these factors. The Kansas State Board of Agriculture publication, Price Patterns, provided price indexes used in adjusting dollar values of inputs and outputs to the 1910-14 base period. These publications provided the major portion of the data used in the analysis.

Adjustments in Available Data

Several adjustments were made in the data in preparation for the analysis. These adjustments were: (1) the adjustment of livestock production value by subtracting feed costs in order to eliminate double accounting of value of feed; (2) the adjustment of dollar values to the 1910-14 base period by using price indexes based on 1910-14 average prices; (3) the land and building values were calculated on the basis of cost of ownership for each year; (4) the machine costs were computed to include cost of ownership and cost of operation for each year; (5) the cost of animal power was figured as a cost of yearly ownership; (6) the value of farm labor was computed on the basis of an average annual wage; (7) crop production figures in bushels of corn, wheat, oats, barley, and grain sorghum were adjusted by rainfall indexes to reduce the influence of rainfall on crop production in Kansas; and (8) total output figures for each five-year point in time were computed by using a five-year moving average.

The adjustment of the value of livestock production was necessary to arrive at an accurate value of total agricultural output for each year. Annual production of livestock was

multiplied by a percentage factor compputed by the U.S.D.A. This product represented the total value of feed fed to livestock. The value of the feed was subtracted from total livestock value to eliminate double accounting of feed grains produced during the year.

The dollar values of all inputs and outputs were adjusted by price indexes to correct dollar values to the 1910-14 base period. Total output was adjusted as one unit by the price index of prices received by farmers. Each input was adjusted by the price index corresponding to itself (i.e., labor input was divided by the price of labor index). Each input was adjusted by this method in an attempt to measure accurately the quantitative value of each input. The objective of the author was to eliminate as much of the qualitative change as possible in each of the inputs.

Land and building values were adjusted by multiplying the interest rate on real estate and the recorded value of land and buildings each year. This calculation gave the cost of owning land and buildings each year in the form of an opportunity cost.

Total output figures were computed by using a five-year moving average of the yearly production figures expressed in constant 1910-14 dollars. The decision to calculate total output in this manner was not made until after a graphic comparison was made of three methods of computing total output during the 1937-1954 period. This comparison is presented in Fig. 1. Actual production values, adjusted only by the 1910-14 index of prices

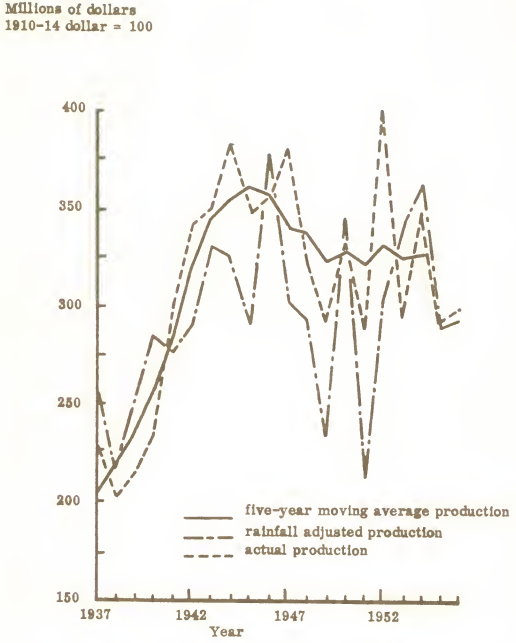

Fig. 1. Changes in total agricultural production for Kansas showing actual production, production adjusted by a rainfall factor, and five-year moving average, 1937-56.

Source: Tables 3, 4 and 6. Appendix.

received by farmers, were plotted as one measurement of total output. Another measure of total output was made by computing a five-year moving average for each total output value from the actual production values. The third measure of total output was computed using crop production values of corn, wheat, oats, barley, and grain sorghum that had been adjusted by a rainfall index to reduce the influence of rainfall on the production of Kansas agriculture, and then added to the remaining actual production figures.

Both the actual production measure of total output and the rainfall adjustment measure of total output showed wide year-to-year fluctuations in total output. On several occasions the rainfall adjustment measure, which supposedly would reduce the fluctuations in total output measured by actual production figures, actually accentuated the fluctuations in total output. This occurred in years of high rainfall when excessive rain decreased yields instead of contributing to higher yields, and in years of below average rainfall in which output did not decrease correspondingly. Thus, the accuracy of the rainfall adjustment measure of total output is seriously questioned.

The five-year moving average measure of total output, on the other hand, tended to eliminate wide fluctuations in the year-to-year total production values caused by the influence of erratic conditions such as climatic conditions, disease, depression, war, etc. However, it undoubtedly would also exclude changes in total output that were not due to erratic or extreme conditions.

Nevertheless, it was concluded by the author that the five-year moving average measure of total output represented the most accurate measure of the general trend of Kansas agricultural production of the three methods demonstrated in Fig. 1.

Machine costs for each year were calculated by multiplying a yearly depreciation factor times the total value of machines to give the cost of ownership. The factor included the depreciation costs and cost of repairs. The factor used in this adjustment was obtained from a Kansas State University bulletin, "The Cost of Using Farm Machinery," published by the Engineering Experiment Station. Then, the cost of operation was computed by adding the expenditures for gasoline and oil. These expenditures for gasoline and oil were recorded in the Census of Agriculture data. The sum of the cost of ownership and cost of operation gave the machine costs for each five-year interval in the analysis.

The cost of animal power was obtained by dividing the total value of horses and mules by the number 15 or the average length of life. This calculation gave an estimate of the yearly cost of ownership of animal power.

The value of farm labor was computed by multiplying the total number of workers, both family and hired, by an average annual wage computed from U.S.D.A. figures on farm labor.

Wheat, corn, grain sorghum, oats, and barley production figures were adjusted to reduce the influence of rainfall variations on production during the period of Kansas agricultural

production from 1937 to 1957. This adjustment was done by dividing an index based on average rainfall for the period 1937-57 in each county into the corresponding county production figure for each crop for each year in the period 1937 through 1957. All crop production figures adjusted by the rainfall index were then multiplied by the average yearly prices for each crop to give total crop production a dollar value.

Methods of Analysis

After total input values and total output values for each five-year interval in the period 1909 through 1954 were computed, ratios of productivity then were calculated for total input, land, labor, and capital. These ratios expressed in constant 1910-14 dollars, the dollar value of output per dollar of total input, the dollar value of output per dollar of labor cost, and the dollar value of output per dollar of capital expenditure. These ratios were calculated for each five-year interval starting with 1909 and ending in 1954. This method of analysis did not show changes in the productivity of each particular input. These ratios showed the general trend of productivity of Kansas agriculture measured by four different means. This method of analysis enabled the author to evaluate the accuracy of each means of measuring productivity.

Using the ratios of productivity of Kansas agriculture, indexes were computed for the total land, labor, and capital input measurements of productivity. The indexes were all

computed using the 1909 value as equal to 100. These indexes provided measurements of the productivity of agriculture in Kansas as a whole. Increases or decreases over time in the indexes of a particular input or total input represented changes in the productivity of Kansas agriculture over time. These indexes of productivity, then, were measurements of technological progress in Kansas agriculture.

The next method of analysis was the calculation of the average annual rate of technological progress in Kansas agriculture. This analysis necessitated the computation of an index of total output and an index of total input for the period 1909 through 1954. Each index was computed by dividing the 1909 value into the remaining yearly values. The 1909 value equaled 100. Having computed the index of total output for the time period, a linear regression line was fitted to the index using the least-squares method. This regression line was assumed to represent the average annual rate of change in total output. Next, a linear regression line was computed from the index of total input in Kansas agriculture for the 1909-1954 period. This regression line was assumed to represent the average annual rate of change in total input. The net change in total input from 1909 to 1954 was then subtracted from the net change in total output from 1909 to 1954. This calculation gave the total change in output relative to input.

Computing the average annual rate of technological progress was then a matter of dividing the total change in output relative to input by 45, the number of years in the analysis.

The author recognized that a significant change in the trend of total input relative to total output took place during the last one-third of the period 1909-1954. Therefore, an analysis of changes in total output relative to total input was made for the period 1937 through 1956. The method of analysis used in this time period was similar to the method used for the 1909-1954 period. However, in this analysis total output values included crop production values that had been adjusted by a rainfall index designed to reduce the influence of rainfall on crop production. The crop production values for wheat, corn, oats, barley, and grain sorghum were adjusted by the rainfall index. This measurement of total output was designed to provide a more accurate measure of the total agricultural production attributable to the conventional factors of production. The total input values used in this analysis were the same as those used in the previous input-output analysis during the period 1939 through 1954.

Linear regression lines were then computed for total output and total input during the period 1937 through 1956. Using the regression line for total output, the net change in total output was calculated for the period 1937 through 1956. The regression line for total input was used in the same manner to compute the net change in total input for that time period. The net change in total output was expressed as a percentage change from the 1937 value of total output. The net change in total input was also expressed as a percentage change from the 1937 value of total input.

Another method of analysis used in the study was designed to compare the relative quantities of land, labor, and capital employed in the production of Kansas agricultural products during each year in the period 1909-1954. The values of land, labor, and capital were expressed as a percentage of the total value of inputs for each year in the analysis. This method of analysis allowed the author to study the changes in the relative values of land, labor, and capital as parts of the total bundle of inputs. This analysis also showed the long-run trends of shifts in the relative importance of each conventional factor of production.

The next step in the analysis was an attempt to isolate the influence of technology and unexplained variables on Kansas agricultural production. The unexplained variables were such influences as government agricultural programs, depression, war, and climatic conditions other than rainfall. The influence of technology and unexplained variables was considered to be that quantity of total output above the level of inputs. By subtracting the value of total input from the value of total output for each year in the analysis, the author isolated the value of production attributable to the influence of new technology and unexplained variables. The value of production attributable to technology and unexplained variables for each year in the analysis was important in demonstrating how steady the flow of technology into Kansas agricultural production has been over the 1909-1954 period.

The final method of analysis employed in the study was designed to determine the degree of association over time between the changes in total input into Kansas agriculture and the changes in total output of Kansas agriculture, between the changes in each input into Kansas agriculture and the changes in total output, and between each input and every other input into Kansas agriculture. The analysis was a multiple correlation analysis programmed on the IBM 650. This analysis covered the period 1937 through 1956.* The total output figures used in the analysis were production figures computed with crop production adjusted for the influence of rainfall. Total input figures were available only for five-year intervals corresponding to agricultural census years. The total input figures for the years between every fifth-year interval were estimated by the author as steady year-to-year changes in value from one five-year value to the next five-year value.

The coefficient of correlation and the coefficient of determination were computed to express the relationship between total output and the land input, the labor input, the fertilizer input, the seed input, the machine input, the animal-power input, the agricultural extension research input, and the total input during the period 1937 through 1957. In addition, the coefficient of correlation was computed by simple correlation analysis

* This part of the analysis was limited to the 1937-1956 period because of limitations on available output data for grain sorghum production before 1937.

for each individual input with every other individual input and for each individual input and total output. A high degree of correlation was considered to mean that a close relationship may have existed between changes in total input and changes in total output, and between changes in individual inputs and changes in other individual inputs. This method of analysis was designed to enable the author to point out what factors of production have made significant contributions to Kansas agricultural production during the 1937-56 period.

RESULTS AND CONCLUSIONS OF THE ANALYSIS

Results of the Analysis

The ratios of productivity, expressed as output per unit of total input, output per unit of land, output per unit of labor, and output per unit of capital were presented graphically in Fig. 2. These ratios, representing four different means of measuring productivity, were plotted to display the general trends in technological progress in Kansas agriculture over time. The terms, "technological progress" and "increases in productivity" were used interchangeably in the following discussion of the analysis.

The output per unit of capital input showed a distinct downward trend in the productivity of Kansas agriculture over the 1909-1954 period. The capital input measure showed a moderate increase in productivity from 1909 to 1924. However, after 1924,

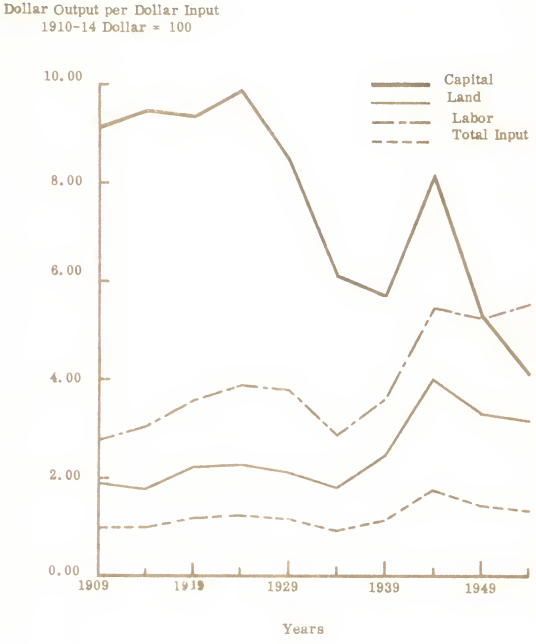

Fig. 2. Changes in productivity for four categories of inputs: total, land, labor, and capital used in Kansas Agriculture 1909-54.

Source: Table 5, Appendix.

productivity measured by this method declined steadily except for a sharp increase during the World War II years.

The output per unit of land input and the output per unit of total input showed similar trends in Kansas agriculture during the 1909 to 1954 period. These measures of technological progress indicated that productivity of land increased slightly during the time period from 1909 to 1924, but then decreased from 1924 to 1934 back to the 1909 level. After 1934, the productivity of Kansas agriculture measured by land inputs and total inputs increased rapidly, reaching a peak in 1944. Following the high in 1944, these measures of technological progress showed a general decline in the productivity of Kansas agriculture.

The fourth measure of productivity, output per unit of labor input, showed the same general trend in technological progress as did the total input and the land measures of productivity with the exception of the 1949-1954 period. The labor input measure showed an increase in productivity from 1949-1954. All other measurements of productivity showed a decrease in productivity during the five-year period. The increase in productivity during the period 1909 to 1954, measured by the output per unit of labor input, was greater than the increase measured by either the land input or the total input measure.

These four measurements of technological progress in Kansas agriculture indicated a variation in the general trend of productivity, depending on the method of measurement, during the time period under study. This led the author to conclude that

certain measurements of the general trend of productivity in Kansas agriculture were more accurate than others. Whereas Vernon W. Ruttan, in his study on technological progress in the meat packing industry, found that the use of the output per unit of labor input measure understated the contribution of technological change to output, the labor input measure of productivity in this study on technological progress in Kansas agriculture overstated the contribution of technological change to output.[39] Ruttan considered the understatement of productivity by the output per unit of labor measure to be the effect of technological progress occurring primarily as a result of capital-saving techniques. This study of technological progress in Kansas agriculture indicated that new techniques have been labor-saving and capital-using. New techniques have indicated their labor-saving and capital-using qualities by the decrease in the size of the labor input and the increase in the size of the capital input during the 1909-1954 period. These changes in the capital and labor resources have occurred at a time when new techniques have contributed to technological progress. Therefore, the author concluded that the output per unit of labor input measure of technological progress has overstated the contribution of technological change to output.

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[39] Vernon W. Ruttan, "The Contribution of Technological Progress to Farm Output," The Review of Economics and Statistics, Vol. XXX, May 1948, p. 62.

The output per unit of capital input measure of productivity was considered less accurate than either the land input or total input measure of productivity because of its understatement of the contribution of technological change to output. The understatement made by the capital input measure was attributed to the use of capital-using techniques in the technological progress in Kansas agricultural production.

The output per unit of land input, and output per unit of total input appeared to be the most accurate measurements of the general trend of technological progress in Kansas agriculture during the time period under study. The output per unit of total input measure of productivity modified the influence of changes in the value of labor and capital since changes in labor input often offset changes in capital input, and both of these inputs were added in figuring total input. Thus, the output per unit of total input measure of productivity was not as biased in its measure of changes in productivity of Kansas agriculture as were the labor input and capital input measures. The bias indicated in the labor input and capital input measures of productivity resulted from the introduction of labor-saving and capital-using techniques.

The output per unit of land input, by showing only moderate changes in value over time, indicated that it remained relatively constant over time, thus serving as a relatively unbiased measure of the productivity of Kansas agriculture.

The indexes of technological progress, computed from the ratios of productivity for land, labor, capital, and total input, were presented graphically in Fig. 3. These indexes, representing four different measurements of the contribution of technological change to output, were plotted to show the magnitude of change in technological progress in Kansas agriculture over time.

The index of technological progress, measured by output per unit of capital input, rose from 100 in 1909 to a high of 108 in 1924; then decreased steadily to a low of 45 by 1954. This index rose sharply from 62 to 88 during the World War II period, 1939 to 1944. The ineexes of output per unit of land input, output per unit of labor input, and output per unit of total input all increased rapidly during this time period, indicating a strong stimulus to increased productivity attributable to the influence of war. The index of output per unit of capital input decreased 55 percent during the period 1909 through 1954. This was a marked decrease in productivity for the period and is a divergence from the general trend of productivity presented by the other three measurements of technological progress. This trend was attributed primarily to the threefold increase in the capital input during the time period under study.

The index of technological progress, measured by output per unit of land input, rose from 100 in 1909 to 117 in 1924. This increase in productivity was followed by a decrease to a low of 92 in the depression year 1934. The index of output per unit of land showed the greatest increase in productivity during the

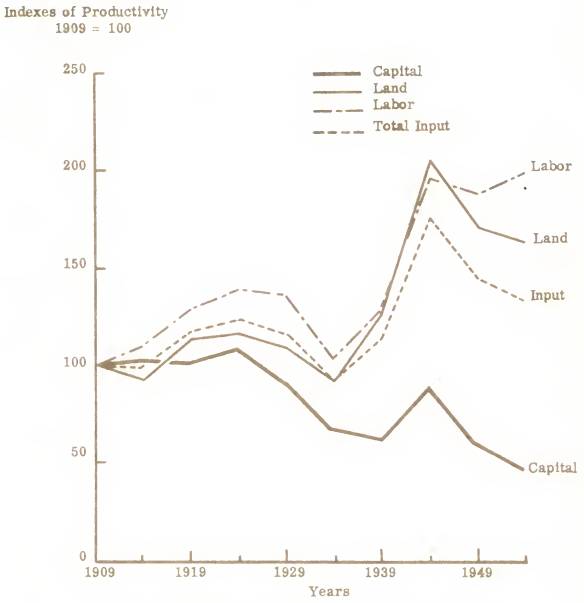

Fig. 3. Changes in the productivity of the factors of production used in Kansas agriculture, 1909-1954.

Source: Table 5, Appendix.

period 1934 to 1944 of any of the indexes by moving from a low of 92 to a high of 204. This increase was largely the result of a 27 percent decrease in the constant dollar value of the real estate (land) input during this time period. The peak in 1944 was followed by a steady decrease in productivity to an index of 162 in 1954. This index showed a total growth in technological progress of 62 percent from 1909 to 1954. This is the second largest increase in productivity of Kansas agriculture recorded by the indexes.

The index of technological progress, measured by the output per unit of labor input, rose from 100 in 1909 to 139 by 1924. This represented the largest increase in productivity recorded for this time period by any of the indexes. This index recorded a decrease in the productivity of Kansas agriculture during the period 1924 to 1934 similar to the decrease recorded by all indexes during this time period. The period 1934 to 1944, again, indicated a rapid growth in productivity by moving from an index low of 103 in 1934 to an index of 194 in 1944. The index of output per unit of labor made a unique movement in the decade of 1944 to 1954 by showing an increase in productivity of three percent. All other indexes decreased during this time period. This index showed the greatest total growth in technological progress during the 1909 to 1954 period with an increase of 97 percent. These large increases in productivity, measured by the output per unit of labor input, were attributed primarily to the nearly 30 percent decrease in the constant dollar value of the labor input during

the time period under study.

The output per unit of total input index of technological progress showed a moderate total increase in technological progress of 32 percent during the 1909 to 1954 period. This index followed the general pattern plotted by the output per unit of land input index during the period under study. The output per unit of total input index did not, however, show as great an increase in productivity during the 1934 to 1944 period as did the land input index. Generally speaking, the index of output per unit of total input moderated the extreme movements of the other three inputs since changes in labor, capital, or land tended to offset each other.

The annual rate of technological progress was computed from data presented graphically in Fig. 4. The linear regression line (trend in total output, 1909-1954), A, represented the average annual percentage change in total output. The linear regression line (trend in total input, 1909-1954), B, represented the average annual percentage change in total input. The total value of output in 1954 was 43 percent greater than the 1909 value of total output. The total value of input for 1954 was four percent less than the 1909 value of total input. By adding the total increase in output to the total decrease in input, the total change in output relative to input was computed. The 47 percent growth in productivity of Kansas agriculture during the period under study was attributed to the contribution of technological change and unexplained variables to output. The 47 percent growth was

divided by the 45-year time period under study to obtain a 1.05 percent annual rate of technological progress for Kansas agriculture during the 1909 to 1954 period.

Studies made by Barton and Cooper on the relation of agricultural production to inputs for the entire United States during the period 1919 to 1947 showed that output increased relative to input by slightly more than 30 percent. Their studies indicated the annual rate of technological growth for this period was approximately 1.04 percent per year.[40] In other studies on annual rates of technological progress, Edwin Holm, in his work on the entire United States economy, estimated the annual rate of technological progress for the national economy to be approximately 1.8 percent per year.[41] Vernon Ruttan, in his studies of the meat packing industry, indicated that technological progress took place at an annual rate of growth of almost one percent per year.[42]

This study indicated that the estimated annual rate of technological progress in Kansas agriculture has been nearly the same as the Barton and Cooper estimated annual rate of technological growth for the entire United States agricultural sector of the national economy. As compared to Holm's study, the technological

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[40] Glen T. Barton and Martin R. Cooper, "The Relation of Agricultural Production to Imputs," The Review of Economics and Statistics, May 1948, p. 123.

[41] Vernon W. Ruttan, "Technological Progress in the Meat Packing Industry, 1919-47," U.S.D.A. Marketing Research Project No. 59, Jan. 1954, p. 9.

[42] Ibid.

progress in Kansas agriculture tended to lag behind the estimated rate of growth for the entire national economy. However, the study by Ruttan only indicated that one industry closely related to agriculture may not be enjoying any faster annual rate of technological progress than the annual rate of growth in Kansas agriculture.

In addition to computing the annual rate of technological progress for the entire period 1909 to 1954 from the data present in Fig. 4, the change in output relative to the change in input for the period 1937 through 1956 was calculated from the data presented in Fig. 4. The linear regression line (trend in total output, 1937-1956), C, represented the average annual percentage change in total output for that period. The linear regression line (trend in total input, 1937-1956), D, represented the average annual percentage change in total input for that period. The total value of output in 1956 was four percent greater than the 1937 value of total output. The total value of input in 1956 was 21 percent greater than the 1937 value of total input. The change in the constant dollar value of total resources or input employed in Kansas agriculture, and the change in the constant dollar value of total production or output of Kansas agriculture indicated that the productivity of Kansas agriculture declined 17 percent during the 1937 to 1956 period.

This time period was considered significant because of the rapid increase in total input after 1944 relative to a moderate decrease in total output from 1944 to 1954. The 1937 to 1956

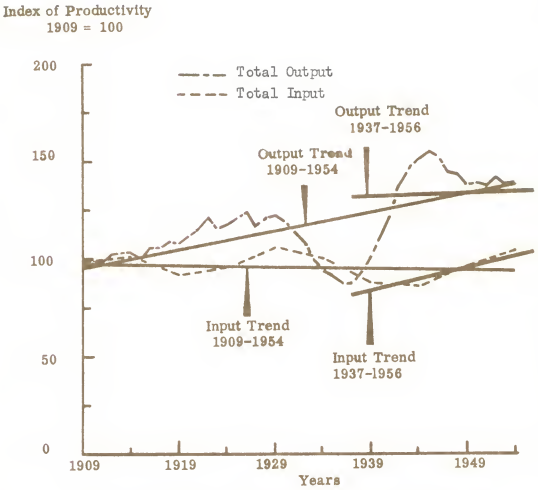

Fig. 4. Changes in the total output produced and total inputs used by Kansas agriculture, 1909-54: with trend lines for two periods, 1909-54 and 1937-1956.

Source: Tables 3 and 4, Appendix.

period began in a decade of economic depression and dry weather which, when combined, tended to limit the production of agricultural products in Kansas. The early 1940's influenced the production of agricultural products quite differently than did the 1930 decade. Agriculture during the early 1940's was stimulated by the war economy and wet weather suited to agricultural production. The author assumed for the purposes of analysis that the low production due to depressed business conditions and poor weather conditions were offset by the high production due to the war years and good weather conditions. Proceeding on this assumption, the linear regression line for total output was considered representative of the general trend of production during the 1937 to 1956 period. Consideration was given to the influence of government price and income stabilizing programs during the latter part of the 1937 to 1956 period. The limitations involved in an accurate measure of the influence of government programs on output led the author to assume for the purposes of analysis that the limitations on production in the form of acreage controls were offset by the reduction in uncertainty in decision-making by the farmer, thus enabling him to maintain or slightly increase production. However, the significant increase in the employment of inputs, primarily capital inputs, during the latter years of the 1937 to 1956 period indicated that output-increasing technology was not readily forthcoming during this time period.

The quantity of output attributable to the influence of technology and unexplained variables was calculated by subtracting

total output from total input in each of the agricultural census years between 1909 and 1954. These quantities of output were tabulated in Table 1. The purpose of this analysis was to obtain an indication of the evenness or unevenness of the flow of technology over time. The values of output attributable to the influence of technology and unexplained variables were displayed graphically in Fig. 5. It was observed that little evidence was available that the flow of technology into Kansas agriculture occurred evenly over time. However, if true estimates for the nine years between 1930 and 1944 could be made by taking out the influence of climatic conditions, depressed business activity, and war, a different picture of the contribution of technological change to output may have been presented. The picture may have been one of a gradual increase of output due to technology until about 1944, then, followed by a slight decline in the influence of technology on output. This would have indicated a relatively smooth flow of technology over time. However, Fig. 5 does not provide substantial evidence on which to base a conclusion as to the constancy of the flow of technology into Kansas agriculture.

The results of computing the percentage of each classification of resources, namely labor, land, and capital, showed two distinct movements in the relative employment of resources. The tabulated results of this part of the analysis were presented in Table 2. The use of labor as a major input in 1909 decreased both in absolute quantity and as a percentage of the total bundle of resources. The other distinct movement was the advance of

Table 1. Changes in the value[1] of total output attributed to the influence of technology and unexplained variables in Kansas agriculture, 1909-1954.

Year	Total output 5-year moving average	Total input 5-year intervals	Value of production due to technology and unexplained variables[2]
		(000)'s	
1909	232,459	227,220	5,239
1914	243,700	238,838	4,862
1919	253,060	211,019	42,041
1924	276,080	219,571	56,509
1929	288,655	244,659	43,996
1934	218,665	232,536	-13,871
1939	235,581	202,676	32,905
1944	354,771	198,282	156,489
1949	322,709	220,379	102,330
1954	324,990	240,438	84,552

[1] Dollar values expressed in terms of 1910-14 prices.

[2] Computed by subtracting total inputs from total output.

Source: Tables 3 and 4, Appendix.

Table 2. The value[1] of land, labor, and capital, and their percentage of total input values for each five-year interval in Kansas agriculture, 1909-1954.

Year	Land (000)'s	% of total inputs	Labor (000)'s	% of total inputs	Capital (000)'s	% of total inputs	Total input (000)'s
1909	118,438	52	83,425	37	25,357	11	227,220
1914	133,623	56	79,537	33	25,678	11	211,838
1919	113,536	54	70,476	33	27,008	13	211,019
1924	120,628	55	70,976	32	27,571	13	219,571
1929	134,486	55	75,952	31	34,222	14	244,659
1934	120,539	52	76,242	33	35,755	15	232,536
1939	95,774	47	65,448	32	41,453	21	202,676
1944	88,882	45	65,554	33	43,845	22	198,282
1949	97,513	44	61,699	28	61,168	28	220,379
1954	102,416	43	59,104	25	78,918	32	240,438

[1] Dollar values expressed in terms of 1910-14 prices.

Source: Table 4, Appendix.

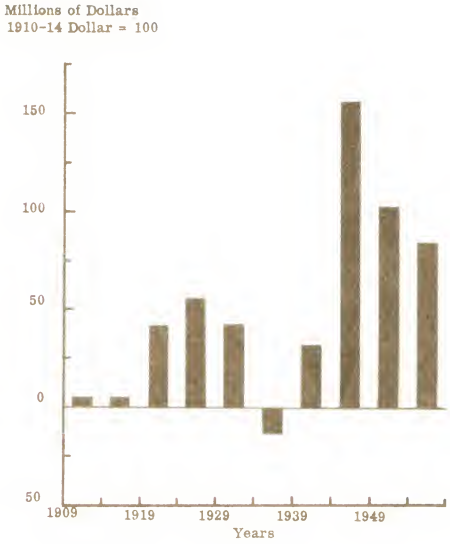

Fig. 5. Total output attributable to technological change and unexplained variables in Kansas agriculture, 1909-1954.

Source: Table 1, page 55.

capital from a minor input in 1909 to a major input by 1954. The capital input increased both in absolute quantity and as a percentage of the total bundle of resources. These trends were presented graphically in Fig. 6.

Labor decreased from a total value of $83,425,000 in 1909 to a value of $59,104,000 in 1954. Percentage-wise, labor decreased from 37 percent of total inputs in 1909 to 25 percent of total inputs in 1954. The capital input, on the other hand, increased in absolute quantity from a value of $25,357,000 in 1909 to a high of $78,918,000 in 1954. The capital input increased from a level of 11 percent of total inputs in 1909 to a level of 32 percent of total inputs by 1954. While labor value was decreasing and capital value was increasing, land value remained nearly constant until 1934, when land value decreased from a value of $120,539,000 in 1934 to a low of $88,882,000 in 1944. However, land value in absolute terms increased steadily after 1944, but continued to decline slowly as a percentage of total inputs.

The final method of analysis used in this study was designed to show the coefficients of correlation and coefficients of determination between total input and total output of Kansas agriculture over time, between total output and each input: land, labor, fertilizer, seeds, machines, animal power, and agricultural research, and between each input mentioned and every other input employed in the production of Kansas agriculture during the 1937-1956 period.

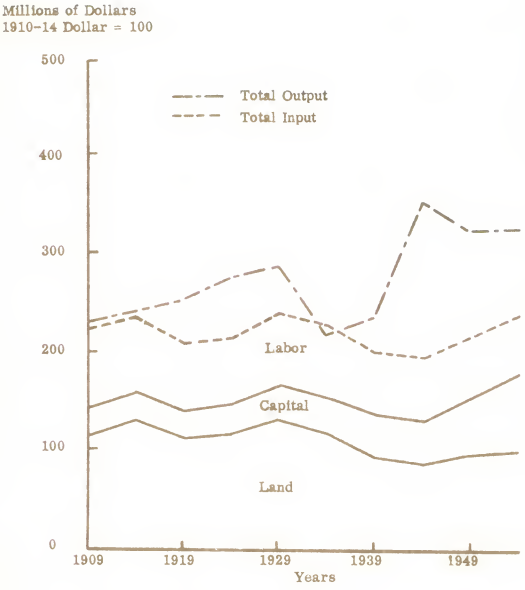

Fig. 6. The total annual output and annual input, total and by categories, for Kansas agriculture, 1909-1954.

Source: Table 2, page 55.

The attempted analysis was a multiple correlation analysis programmed on the IBM 650. This analysis was an experiment using the available input-output data in an effort to show some significant coefficients of correlation and determination. However, the results of the multiple correlation analysis were not sufficiently significant to provide a basis for drawing results. Several factors contributed to the decision not to draw any conclusions from the analysis. They were: (1) the study covered only 20 years; (2) the study had only seven independent variables and one dependent variable; (3) the coefficient of determination for the total input-total output correlation was only 0.50; and (4) interrelationships existed between the independent variables, thus tending to reduce the percentage change in total output explained by total input. These factors led the author to conclude that no conclusions could be accurately drawn from the analysis.

Summary of Conclusions

In summary, the author concluded that, generally, new techniques affecting the production of Kansas agriculture during the 1909 to 1954 period have been labor-saving, capital-using, and output-increasing. The period from 1944 to 1954 did not indicate that output-increasing technology or input-saving technology were readily forthcoming in Kansas agricultural production, but this period did indicate the influence of labor-saving and capital-using techniques.

Changes in the quantity of the labor input and the productivity of Kansas agriculture, measured by the labor input over time, led the author to conclude that the influence of new technology introduced into Kansas agriculture over the 1909 to 1954 period had been largely labor-saving in nature. Observation of the growth of capital inputs during this same period showed that new technology also had been highly capital-using in nature.

Changes in total output relative to total input indicated that new technology affecting production also was output-increasing during the first 30 to 35 years of the study. This conclusion was supported by an increase in total output while total inputs remained relatively constant. However, output-increasing technology was lacking in sufficient quantity to continue expanding output relative to inputs during the period from 1944 to 1954. This conclusion was supported by a relatively stable level of total output while total input was steadily increasing.

The computed 1.05 percent annual rate of technological progress in Kansas agriculture compared favorable to the annual rate of technological progress for agriculture on a national basis computed in the study by Barton and Cooper.[43] However, this study on Kansas agriculture indicated that since 1944, which marked the end of Barton and Cooper's study on technological progress, the productivity of Kansas agriculture, measured in terms of output per unit of total input, by 1956 had decreased nearly 17 percent.

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[43] Barton and Cooper, op. cit., p. 123.

The explanation for the decrease in productivity was relatively obscure in the analysis. Diminishing returns to additional units of capital may account for the slower rate of growth in output during this period. The author concluded that the introduction of output-increasing techniques into Kansas agriculture during this period had not kept pace with the increased use of input-increasing techniques. New techniques have resulted largely in an increase in the expenditures on capital inputs to replace labor in the production process during the 1944 to 1956 period.

Two conclusions were made by the author regarding the accuracy of methodology employed in the analysis of data in this study: (1) the output per unit of total input was the most accurate measure of changes in productivity in Kansas agriculture during the 1909 to 1954 period (page 45), and (2) the five-year moving average was the most accurate measure of the general trend of total output of Kansas agriculture over the period of time under study (page 34).

ACKNOWLEDGMENT

The guidance and assistance given by John B. Sjo, Assistant Professor of Agricultural Economics, Kansas State University, in the preparation of this thesis are gratefully acknowledged.

Lee Teaford and Thomas Hamilton, Department of Mathematics, are recognized for their assistance in programming on the IBM 650.

The helpful suggestions of Dale A. Knight, Associate Professor of Agricultural Economics, Kansas State University, were deeply appreciated.

The suggestions of others in the Department of Economics and Sociology, Kansas State University, were also appreciated.

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APPENDIX

Table 3. The value[1] of crop production, livestock production, and total output of Kansas agriculture, 1909-1954.

Year	Crop production	Livestock production (000)'s	Total output[2]	1910-14 prices received index	Total output adjusted (000)'s	5-year average	5-year average total output index
1909	215,057	34,786	249,843	101	247,369	232,459	98
1910	202,409	36,113	238,522	100	238,522	233,146	99
1911	172,837	40,547	213,384	89	239,757	231,285	98
1912	227,835	34,736	262,521	101	259,971	240,139	102
1913	132,471	40,045	172,516	101	170,808	242,531	103
1914	279,971	34,999	314,970	108	291,639	243,700	103
1915	251,889	33,661	285,550	114	250,482	235,427	100
1916	273,110	36,351	309,461	126	245,604	248,412	105
1917	392,822	42,199	435,021	199	218,604	246,731	105
1918	442,091	55,306	497,397	211	235,733	254,865	108
1919	564,346	67,264	631,610	223	283,233	253,060	107
1920	531,585	65,277	596,862	205	291,152	261,382	111
1921	221,353	53,079	274,432	116	236,579	269,441	114
1922	246,310	45,132	291,442	112	260,216	284,367	121
1923	260,639	51,269	311,908	113	276,025	270,567	115
1924	378,707	50,731	429,438	120	357,865	276,080	117
1925	280,620	57,048	337,668	152	222,150	282,584	120
1926	316,688	61,041	377,729	143	264,146	289,163	123
1927	347,220	62,607	409,827	140	292,734	273,947	116
1928	382,593	62,256	444,849	144	308,923	282,523	120
1929	311,087	86,230	397,317	141	281,785	288,655	122
1930	228,229	79,204	307,433	116	265,028	279,255	118
1931	167,013	59,988	227,001	77	294,806	268,011	114
1932	90,478	44,676	135,154	55	245,735	255,107	108
1933	119,844	39,360	159,204	63	252,705	235,874	100
1934	139,102	40,851	179,953	83	216,811	218,665	93
1935	137,424	55,594	193,018	114	169,314	215,682	91
1936	188,071	52,008	240,079	115	208,764	205,588	87
1937	233,724	57,109	290,833	126	230,820	205,076	87
1938	141,536	52,607	194,143	96	202,232	217,909	92
1939	138,511	60,743	199,254	93	214,252	235,581	100
1940	170,661	65,155	235,816	101	233,481	257,558	109
1941	276,221	89,237	365,458	123	297,120	286,974	122
1942	383,571	137,710	521,281	153	340,707	320,678	136
1943	456,400	175,854	632,254	181	349,312	343,268	146
1944	558,781	141,693	700,474	183	382,773	354,771	150
1945	513,610	148,067	661,577	191	346,428	362,884	154
1946	629,947	164,436	794,383	224	354,635	357,686	152
1947	912,364	200,953	1,113,317	292	381,273	339,020	144
1948	730,309	204,097	934,406	289	323,324	336,379	143
1949	538,665	190,729	729,394	252	289,442	322,709	137
1950	679,893	213,146	893,939	268	333,224	326,420	138
1951	614,378	281,690	896,068	313	286,284	319,779	136
1952	944,554	230,944	1,175,498	294	399,829	331,410	140
1953	556,911	188,690	745,601	257	290,117	322,756	137
1954	675,012	183,560	858,572	247	347,600	324,990	138

[1] Dollar values expressed in terms of 1910-14 prices.

[2] Total output was computed by adding crop production and livestock production.

Table 4. The value[1] of land and buildings, farm labor, machines, seeds, animal power, fertilizer, research, and total inputs used in Kansas agricultural production, 1909-1954.

Year	Land and buildings	Farm labor	Machines	Seeds	Animal power	Fertilizer	Research	Total input value[2]	Total input index
	(000)'s								
1909	118,438	83,425	5,659	13,729	5,790	7	101	227,220	98
1914	133,623	79,537	8,816	11,685	4,569	475	134	238,838	102
1919	113,536	70,476	12,197	10,723	3,446	537	104	211,019	91
1924	120,628	70,976	12,108	13,200	2,227	272	162	219,571	94
1929	134,486	75,952	20,444	11,537	1,696	330	215	244,659	105
1934	120,539	76,242	18,937	14,205	2,213	171	228	232,536	100
1939	95,774	65,448	22,954	16,504	1,251	468	275	202,676	87
1944	88,882	65,554	35,687	7,117	649	35	358	198,282	85
1949	97,513	61,699	45,716	5,939	185	8,897	431	220,379	95
1954	102,416	59,104	60,284	4,980	100	12,695	860	240,438	103

[1] Dollar values expressed in terms of 1910-14 prices.

[2] Total inputs were computed by adding land and buildings, farm labor, machines, seeds, animal power, fertilizer, and research inputs.

Table 5. Changes in the productivity of Kansas agriculture expressed by four categories of inputs: total, land, labor, and capital, 1909-1954.

Year	Output/ total input[1]	Index of inputs	Output/ labor[1]	Index of labor	Output/ capital[1]	Index of capital	Output/ land[1]	Index of land
1909	1.02	100	2.79	100	9.17	100	1.96	100
1914	1.02	100	3.06	110	9.49	103	1.82	93
1919	1.20	118	3.59	129	9.37	102	2.23	114
1924	1.26	124	3.89	139	9.87	108	2.29	117
1929	1.18	116	3.80	136	8.43	92	2.15	110
1934	0.94	92	2.87	103	6.12	67	1.81	92
1939	1.16	114	3.60	129	5.68	62	2.46	126
1944	1.79	175	5.41	194	8.09	88	3.99	204
1949	1.46	143	5.23	187	5.28	58	3.31	169
1954	1.35	132	5.50	197	4.12	45	3.17	162

[1] Dollar values expressed in terms of 1910-14 prices.

Source: Tables 3 and 4, Appendix.

Table 6. The value[1] of crop production,[2] livestock production, and total output of Kansas agriculture, 1937-1956.

Year	Wheat	Oats	Barley	Corn	Grain sorghum	Other crops	Total crop	Price index	Adjusted crop	Adjusted livestock	Total output
						(000)'s					
1937	204,614	14,680	2,361	20,140	7,034	23,602	272,431	128	212,837	45,687	258,524
1938	87,198	8,062	2,146	21,884	5,014	31,851	156,155	77	202,799	46,967	249,766
1939	86,250	9,057	3,437	28,221	8,692	38,768	174,425	74	235,709	55,221	290,930
1940	110,031	17,343	9,233	28,087	13,012	44,694	222,400	86	258,605	56,656	315,261
1941	144,597	13,098	9,402	37,459	8,944	37,940	251,440	98	256,571	61,970	318,541
1942	163,424	16,745	7,543	62,785	11,658	43,007	305,162	121	252,200	76,933	329,133
1943	198,294	29,314	14,358	95,970	17,981	66,213	422,130	152	277,717	85,366	363,083
1944	238,012	19,220	12,098	96,743	33,821	52,976	452,870	170	266,394	73,416	339,810
1945	258,179	9,202	5,796	67,253	17,209	45,889	403,528	174	231,913	71,877	303,790
1946	464,176	34,745	6,715	112,901	17,946	47,358	683,841	204	335,216	68,231	403,447
1947	495,674	33,707	7,133	83,755	17,556	37,960	675,785	276	244,850	65,886	310,736
1948	486,921	23,944	8,512	48,343	29,872	39,976	637,568	249	256,051	60,743	316,794
1949	230,820	11,148	2,648	76,117	24,966	48,285	393,984	215	183,248	64,874	248,122
1950	463,080	20,981	4,507	126,092	40,187	52,242	707,089	224	315,665	67,027	382,692
1951	179,243	9,787	1,283	68,593	52,722	60,953	372,981	249	149,792	73,166	222,958
1952	430,140	13,691	1,555	115,301	38,845	59,279	658,811	261	252,418	69,772	322,190
1953	438,136	22,485	2,408	105,263	55,827	53,742	677,861	245	276,678	69,885	346,563
1954	478,545	35,046	13,087	61,771	65,177	54,669	708,295	242	292,684	72,553	365,237
1955	323,375	23,750	13,198	48,018	35,328	58,538	502,207	237	211,902	73,038	284,940
1956	271,480	26,217	15,105	71,527	62,421	54,571	501,321	229	218,917	72,043	290,960

[1] Dollar values expressed in terms of 1910-14 prices.

[2] Values of wheat, oats, barley, corn, and grain sorghum were adjusted by a rainfall index.

THE INFLUENCE OF TECHNOLOGY ON THE PRODUCTIVITY OF KANSAS AGRICULTURE, 1909-1954

by

GARY WALKER RUMSEY

B. S., Kansas State University, 1959

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Economics and Sociology

KANSAS STATE UNIVERSITY
OF AGRICULTURE AND APPLIED SCIENCE

1960

The purpose of this study was to gain a better understanding of the nature and consequences of technological progress in Kansas agriculture over the period 1909-1954. The study was concerned primarily with the changes in production of crops and livestock relative to the changes in land, labor, and capital inputs in Kansas agriculture as a whole. Therefore, the analysis pursued in this study determined the annual rate of technological progress over the 1909-1954 period and the 1937-1956 period of Kansas agricultural production. The analysis also determined the effects of new techniques on the factors of production employed in Kansas agriculture during this time period.

The methodology used in the study was designed in accordance with the objectives outlined above. The total output of Kansas agriculture was calculated by adding total crop production to total livestock production. Total input into Kansas agriculture was computed by adding total land input, total labor input, and total capital input. Total land input included the value of both land and buildings. Total labor input value included family and hired labor. The total input of capital was computed by adding input value of machines, seed, animal power, fertilizer, and agricultural research. All values were expressed in terms of 1910-14 prices to obtain measurements of quantitative changes. These values were calculated for each five-year interval beginning with 1909 and ending with 1954. From these values the changes in total output relative to total input over time were computed, thus providing a measure of the influence of technology. This study

also recognized that total output was influenced by factors other than the conventional factors of production land, labor, and capital. Thus, the changes in output relative to inputs were attributed to new technology plus unexplained variables.

The output per unit of total input measurement of technological progress in Kansas agriculture was supplemented by measurements of technological progress in the form of output per unit input of labor, output per unit input of land, and output per unit input of capital. These measurements of productivity of Kansas agriculture helped to classify the effect of new technology as being capital-using, labor-saving, and/or output-increasing.

The value of the labor input decreased from a value of $83,425,000 in 1909 to a value of $59,104,000 in 1954. The productivity of Kansas agriculture, measured by the output per unit of labor input measure, showed a steady 97 percent increase in productivity. These figures were contrasted with an increase in the value of the capital input from $25,357,000 in 1909 to $78,918,000 in 1954, and a steady decrease in productivity of Kansas agricultural production, measured by the output per unit of capital input, of 55 percent during the 1909-1954 period. This contrast led the author to conclude that new techniques affecting the production of Kansas agriculture have been labor-saving and capital-using.

New techniques have also been output-increasing as indicated by total output increasing relative to total input at an average rate of 1.05 percent per year during the 1909-1954 period. This

conclusion was indicated by an increase in total output during a time when total inputs remained relatively constant.

The 1937-1956 period of Kansas agriculture was characterized by an unprecedented set of conditions in Kansas agricultural production. The value of total output increased only four percent during this period of time while the value of total input increased nearly 21 percent. This period indicated that output-increasing technology or input-saving technology were not readily forthcoming in Kansas agricultural production.

Two additional conclusions were made by the author regarding the accuracy of methodology employed in the analysis of data in this study. They were: (1) the output per unit of total input was the most accurate measure of changes in productivity in Kansas agriculture during the 1909 to 1954 period, and (2) the five-year moving average was the most accurate measure of the general trend of total output of Kansas agriculture over the period of time under study.